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A CHEMICAL SENSOR AND BIOSENSOR BASED TOTALLY AUTOMATED WATER
QUALITY MONITOR FOR EXTENDED SPACE FLIGHT: STEP ONE

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This report is the result of a literature search to consider what technologies should be represented in a totally automated water quality monitor for extended space flight. It is the result of the first summer in a three year JOVE project.

The next step will be to build a test platform at the Authors' school, St. John Fisher College. This will involve undergraduates in NASA related research. The test flow injection analysis system will be used to test the detection limit of sensors and the performance of sensors in groups. Sensor companies and research groups will be encouraged to produce sensors which are not currently available and are needed for this project

A ground base water lab follows standard methods (4). As technology evolves there is a lag time incorporating the new technologies into standard methods since new methods must be validated and approved by the appropriate government agencies. The priorities for method development for a ground based system vs a space system are almost diametrically opposed, e.g, throughput is a major concern for a ground based system but the sample load will be relatively small in the extended flight system.

A totally automated water quality monitor for extended space flight, e.g., use on the Space Station Freedom, needs to meet the criteria shown in Table 1. It must have sufficient detection limits to analyze for the parameters listed in Table 2 to NASA specifications. Design of a system is aided if an exact list of Organic Toxicants is given rather than general categories, e.g., organic acids. NASA performs evaluations of all materials used in spacecraft to determine candidate compounds, e.g., plasticizer offgases.

Table 1

Water Quality Monitor Criteria

- Totally Automation for routine operation
- Minimal maintenance requirements
 - Low power usage
 - Low weight
 - Low space requirement
 - Low use of expendable items
 - Low use of reagents
 - Minimal sample size
 - Work in Microgravity
 - Withstand Launch
- Meet NASA material limitations
- Meet NASA safety criteria
- Provide data directly to main computer system
- Analyze for parameters listed in Table 2

Table 2

pH
 Conductivity
 Color
 Bactericide
 Turbidity
 Dissolved Gas
 Free Gas
 Inorganic Anions
 Inorganic Cations
 Total Organic Carbon
 Organic Toxicants

Till recently the development of a totally automated water quality monitor would have been built around the same instruments found in earth based analytical laboratories. Methods would evolve around separation based instruments, e.g., liquid and gas chromatography, which use non-specific detectors unless hyphenated system are used such as gas chromatography-Mass spectroscopy where the separation is performed by the first instrument and specific peak identification is done by the second. These instruments are complex, heavy, have relatively high power requirements and require a moderate amount of skill to service and maintain. Figure 1 shows the revolution in water quality related sensor research that has occurred in the late 80's and early 90's.

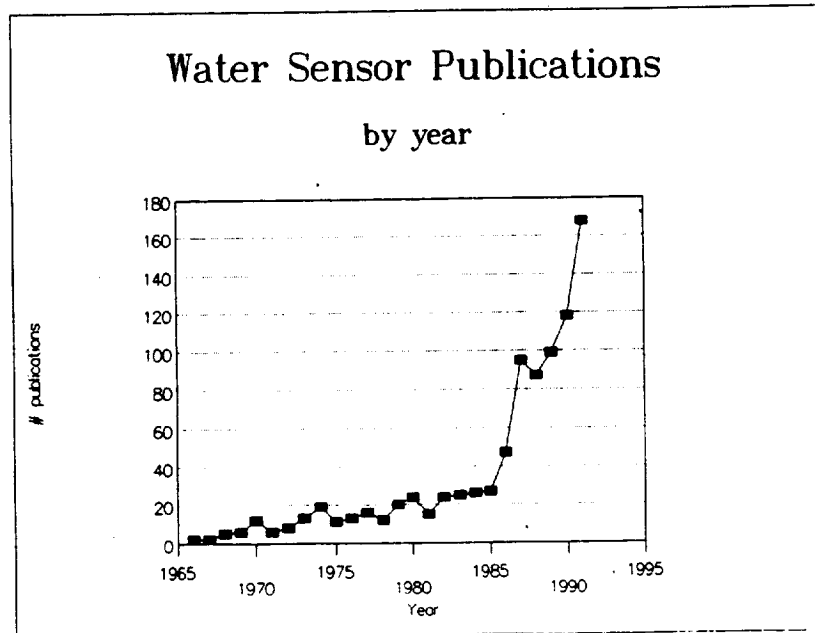


Figure 1

The chemical sensor or biosensor is a link between a chemical system and a computer. The computer handles only numbers in its digital world. Information in the analog world must be converted from voltages to numbers. The chemical sensor provides a link between analyte concentration and a voltage. This completes the chain to get from changing analyte concentration to changing numbers in the computer.

The transducer in a sensor may be potentiometric, amperometric, conductimetric, impedimetric, optical, calorimetric, acoustic, or mechanical (3). A biosensor links one or more of these with a biological material that may be, for example, organisms, tissues, cells, organelles, membranes, enzymes, receptors, antibodies, or nucleic acids. Polymeric materials play an important role in the mating of biomaterials and transducers. They place structural roles as well as active roles in time release of materials and conduction of signals.

Some examples of sensors are ion sensitive electrodes, enzyme electrodes, immunosensors, quartz crystal microbalance, chemically sensitive field-effect transistors, fiber optic, slab waveguide, bioluminescence, and electrochemical. Many variations of sensors have been reported (1).

Ion sensitive electrodes may be used for the inorganic anions, non-metal cations and dissolved gas. The metals can be determined using potentiometric stripping analysis. A diode array spectrometer can determine color, bactericide, turbidity, and free gas. A conductivity cell will be used for conductivity determination. TOC can be determined by commercially available TOC detector. Organic Toxicants can be determined by immunosensors and enzyme based sensors (2).

An extensive list of literature references of sensors for water quality management is available from the author via internet at rss@sjfc.edu. A macro written in Microsoft Word was used to prepare the output from STN searches for entry into Borland's Paradox database program. This allowed offline searches and sorting of the reference material.

The ultimate flow injection system can be envisioned with a backplane for power, signals, reagents, and sample. Ultimately electronic components and sensors will be fabricated on the same wafers to the extent that the output of the sensor package will be network compatible. Sensor modules would plug into this backplane to receive their input needs and give their output on the computer network. The modules could contain their own diagnostics and notify ground control or the astronauts when they need replacing. The astronauts would simply unplug a module that might be the size of a 35mm slide and plug in a new one.

This system would make an ideal candidate for a technology reinvestment or transfer program to be developed as a water quality monitor for home/industrial use. As sensors useful for water quality monitoring are mass produced their cost should drop dramatically. The system could monitor raw water quality to a house and direct the water to in-house purification on a as need basis. It could also monitor the performance of the in-house water purification system. A version of the system could be used for those using unfamiliar water, e.g., travelers, campers, hikers, etc.

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